LUND UNIVERSITY
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Living La Vida Low-Carb: A Low Carbon Society in Latin America. Estimating the Effects of Road Transport Management in Carbon Emissions Through a Visioning-Backcasting Model

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Abstract

Carbon emissions have recently been put under the spotlight since it is widely accepted that global warming is caused by the emission of greenhouse gases, of which carbon dioxide is the main component. One of the fastest rising sources of emissions from carbon emissions is the transport sector, with emissions often rising faster than the GDP growth rates of developing countries. The estimated share of carbon emissions coming from the developing world is currently low, however it is expected to rapidly increase in the next 30 years. It is more often that the developing countries are the most heavily affected from the externalities caused by the increase in global carbon emissions, hence there is an increasing interest in achieving a 'low-carbon' society in both the developed and the developing worlds. Using a visioning-backcasting approach and the ASIF formula, the carbon emissions for the four Latin American countries chosen for this study – Brazil, Argentina, Chile and Mexico – have been estimated. Two images of the future have been created. This paper's results show that for both images envisioned for the backcast, the target reduction of 50 per cent of carbon emissions by 2050 or bring it back to levels of the base year of 2000 can be achieved through a mixture of policy packages targeting road transport management.

Keywords: Brazil, Argentina, Chile, Mexico, carbon emissions, backcasting

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'Fortaleza no es lo que creéis. La fortaleza no se mide según el grosor de los músculos ni según el número de kilos que una persona pueda levantar. Fortaleza significa, sobre todo, aguantar, no romperse.'
- Lucía Etxebarría

Tusen tack to my supervisor, Karl-Johan Lundquist, without whom I wouldn't be able to submit this thesis at all.

Sé que gairebé mai ho dic però mare, ets una persona molt important per a mi, que sense tu no seré ni a deu mil passos a prop d'on sóc ara.

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I. Introduction

Carbon emissions have recently been put under the spotlight since experts have suggested that global warming is caused by the emission of greenhouse gases (GHGs). There is a broad consensus that greenhouse gases are warming the planet (IPCC, 2007). Greenhouse gases, as defined by the Intergovernmental Panel on Climate Change (IPCC), are 'those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of thermal infrared radiation emitted by the Earth's surface, the atmosphere itself, and by clouds' (2007), of which water vapour (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4) and ozone (O_3) are the primary greenhouse gases present in the atmosphere. These GHGs are related to what is called as the 'greenhouse effect', the phenomenon that arises where the GHGs

> 'absorb thermal infrared radiation, emitted by the Earth's surface, by the atmosphere itself due to the same gases, and by clouds. Atmospheric radiation is emitted to all sides, including downward to the Earth's surface. Thus greenhouse gases trap heat within the surface-troposphere system' (IPCC, 2007).

72 per cent of total GHGs emitted into the atmosphere is composed of carbon dioxide (Sanglimsuwan, 2011), hence making it the main cause of global warming. Carbon dioxide is produced in a number of ways such as the burning of oil and gas for energy and fuel, and including other manmade acts such as deforestation. The carbon dioxide emitted into the atmosphere, otherwise known as carbon emissions, have been increasing dramatically over the past 50 years and are still increasing every year. Fossil fuel combustion for the purposes of power, industry and transportation represent the three major economic sectors most liable for carbon emissions in a global scale.

One of the fastest rising sources of emissions from greenhouse gases is the transport sector, and as can be observed in the case of a few developing countries, GHG emissions rise faster than the growth rate of the country's gross domestic product (GDP). The transport sector contributed around 23 per cent of total global carbon dioxide emissions, of which almost all resulting from fossil fuel combustion (IEA, 2009). Authorities, both public and private, in various countries have placed lower priorities in greenhouse gas emissions reduction, and often are more concerned with the adverse effects that excessive emissions lead to, maybe because the externalities linked to the adverse effects from carbon emissions is deemed to create 'lesser damage' than those linked to other transport related issues such as air pollution or traffic congestion.

Understanding the mechanics affecting the increase in carbon emissions from the transportation sector is increasingly more important due to two important aspects. Firstly, the transport sector has been identified as one of if not the most important source of carbon emissions in present society. Secondly, understanding the mechanics would be instrumental in the preparation and proposition of possible mitigation strategies for carbon emissions, and adjoining issues such as climate change. Additionally, much focus on the literature regarding the issues concerned has been directed to the usual suspects: China, India, the rapidly growing Asian economies, and the developed countries bound by the Kyoto Agreement to meet reductions targets. The African continent, the Pacific Islands and the region comprised by Latin America and the Caribbean, especially the four countries chosen in this study who have been exercising their economic muscle and thus their visibility in a global scale, can be considered 'neglected' in terms of literature, as their contributions to global carbon emissions are considered minimal, and more attention and political pressure is focused on the bigger emitters.

The intention of this paper is to test whether emission reduction targets set in the region, or within individual countries, can be achieved and can be shown through the employment of a visioning backcasting model. This paper is structured as follows. Chapter 2 establishes the connections between economic growth, carbon emissions, and the transport sector. Chapter 3 would look into the situation in the developing world in a Latin American perspective in relation to carbon emissions. Chapter 4 will show the emission trends and agents that influence transportation emissions in Latin America. Chapter 5 will state the objectives and scope of this paper Chapter 6 will detail the methodologies employed by this study. Chapter 7 will build the backcasted model. Chapter 8 will determine and quantify the policy packages to be implemented in the estimations. Chapter 9 will display the calculations and interpret the results and Chapter 10 will contain the conclusions and final remarks.

II. Economic Growth, Transportation and Carbon Emissions

Mobility could be considered as an essential human necessity. Economic survival and human interaction depend on the ability to move people and products. The presence of efficient mediums for the purpose of mobility is an important promoter of economic development. Cities would not function and exist, and trade between countries could not happen without infrastructure to transport people and goods in a cheap and efficient manner (WBCSD, 2002). Transport is widely recognised as a significant and increasing source of the release of polluting components into the atmosphere. Many human activities produce GHG emissions, and thus carbon emissions, but roughly two thirds of the total anthropogenic emissions come from fossil fuel combustion from transportation (Schipper et al., 2009).

Schipper et al. (2000) point out a few aspects to consider. Transportation activity is a derived demand. Society and products do not use transportation systems just for the sake of movement. Instead, society and products move around in order from them to be able to access and partake in other activities or products, such as other products, services, markets, places where they could participate in other activities, and of course other members of the society. This ensuing direct demand is for these integrants of economic and social proceedings (that is, the products, services, markets, places where they could participate in other activities, and other members of the society). Schipper et al. (2000) explains further that there are differences in the demand. There exists a first-order derived demand, if it can be seen that there is need for access to economic and social proceedings, and where the word 'access' usually means the use of transportation, however it does not always need to. Transportation systems can be considered as one of a few other ways in which access can be provided, as proximity or telecommunications can also fulfill the requisites demanded by the definition of 'access'. A second-order derived demand, such as in the case of mobility itself, is the demand that is derived directly from the demand for access, which is in turn coming from the demand in order to participate in economic and social activities (Schipper et al., 2000).

The development of an economy and its transport systems are unavoidably connected to each other. As an economy grows, it stimulates the demand for the use of transport systems, whereas this increased accessibility and availability of transportation would in turn incentivise further economic development through facilitating trade and economic specialisation (Kahn Ribeiro et al., 2007). The resulting industrialisation and increased economic specialisation would then stimulate the need for bigger quantities of products and raw materials to be transported from one place to another over often considerable distances. The same goes with the transportation of people from one place to another. The process of globalisation has further hastened these flows of people and goods. To sum up, as economic growth increases, there is an increased impetus for motorisation, which would in turn lead to increased emissions.

The transportation sector has been observed to contribute to a significant percentage of carbon emissions. The same sector has grown very rapidly during the past two decades, owing to the rapid increase in population growth in urban areas, an increased imperative for economic growth, demographic changes, increases in income and changes both in land use and urban planning, all of which has resulted into the increase in transport activities in the urban setting. The rise in urbanisation rates has seen a rapid increase during the past century. Approximately 75 per cent of the population in the developed world, and about 40 per cent in the developing world are now observed to live in urbanised areas (Kahn Ribeiro et al., 2007). Cities have, as a result, grown bigger as well; there are now 27 'megacities' – cities with a population of more than 10 million people – all over the world (Brinkoff, 2012). Another noticeable trend is the decentralisation of cities. As characterised by the megacities, urban areas have extended out at a faster rate than they have populationwise, wherein rapid growth can be witnessed in suburban areas and the emergence of 'edge cities' and 'dormitory towns'. This process of decentralisation has resulted in the stimulation of demand for travel and the creation of a travel pattern that is not easily tended to by public transport systems (Kahn Ribeiro et al., 2007). As a consequence, there has been an increased desire to acquire personal motorised transport, not only of four wheeled vehicles such as cars but also two wheelers such as motorcycles, and a decreasing share of transit. Furthermore, this resulting 'lower-density development' and the increased distances needed by those living in outer areas to access economic functions such as jobs and services have contributed to the decrease in walking and cycling in the share of total travel activity (WBCSD, 2002). Hence the transportation needed to bridge the distances in urban areas influences the amount of GHGs and carbon emissions.

Schipper et al. (2000) however highlights an important point to consider. Irrespective of how people and products transport themselves around, or the levels of vehicle efficiency, the increase in the amounts of the movement they carry out is the most important factor as to why there is an increase in carbon emissions. Such increase, as Schipper et al. (2000) has observed, was connected to the growth in income levels, variable between countries, however it is not straightforward to determine which is leading which. Therefore, if transport activity is one of the causes driving the levels of economic and income up, it would not be desirable for societies developed or developing to restrain the levels of transport activity.

The ratification of the Kyoto protocol and subsequent negotiations such as that of the climate change conferences in Copenhagen in 2009, Cancún in 2010 and Durban in 2011 have also highlighted the relationship between carbon emissions and economic growth. It is argued that the present society is more affected to the externalities at local level, however the results achieved from mitigating carbon emissions are uncertain, as the Kyoto negotiations had witnessed (Schipper et al., 2000). As a result, policies to restrain carbon emissions should be implemented in combination with strategies that would induce a reform to the transport sector.

III. Developing Countries, Latin America and Carbon Emissions

Although the estimated share of carbon emissions coming from the developing world is currently low, it is expected to increase by 45.6 per cent in the 25 year period between 2005 and 2030 (McAndrews et al., 2010). As developing countries are not part of the Annex 1, they are not bound into complying to the often harsh targets applied in ‘developed world countries’ who have signed it in an effort to reduce GHG emissions. However, it is more often that the developing countries are the most heavily affected from the externalities caused by the increase in global GHG emissions. An Asian Development Bank (ADB) study shows that Southeast Asia is one of the more vulnerable parts of the world in terms of climate change externalities. Countries like Thailand, Indonesia, Vietnam and the Philippines could experience damages equivalent to up to 6 per cent of their GDP every year (ADB, 2009) if steps are not taken to mitigate the effects of climate change. The Economic Commission for Latin America and the Caribbean (ECLAC)

(2009) publication echoes the findings regarding the economic effects of climate change in the Latin American context. It reveals the various ways in which countries in the region would be affected by the repercussions, mainly affecting the agricultural sectors of the countries within the region. The impacts of global warming, a phenomenon often linked to the rise of GHGs trapped in the atmosphere, are already being felt in the region in the form of higher temperatures, more hurricanes, loss of glacier and snow mass, extreme rain events and sharp declines in rainfall, amongst others. Climate change also has effects on socio-economic terms. In Mexico and Colombia, the effects on agriculture could be devastating, whereas in Peru, freshwater availability to coastal populations could be threatened (McAndrews et. al., 2010).

In Latin America, carbon emissions produced from the consumption of fossil fuels have seen a rise from 760 million tons in 1980 to 1,327 million tons in 2005, averaging a growth rate of 2.3 per cent a year (Timilsina and Shrestha, 2008). Having said that, Latin America has a relatively small contribution to carbon emissions, compared to the rest of the world. In 2006 the world average emissions per capita was 4.3 metric tonnes whilst Latin American carbon emission per capita was only 2.5 metric tonnes, which would translate to 60 per cent of the world average. Even by 2020 it is projected that Latin American emission per capita will only by a fraction of what is expected of either the US or the EU (McAndrews et al., 2010). Carbon emissions from the transport sector in Latin America are predicted to treble by 2030 due to the expansion of both motorised vehicle ownership and vehicle-kilometres travelled, (Fulton and Eads, 2004; Schipper et al., 2009b). The total emissions would be still a fraction of what is emitted by the developed world, but it is not a discernible amount.

A crucial aspect of countries in the developing world is that the society is still not motorised due to the low incomes within the countries involved. Often the population does not have access to personal vehicles and has limited access of motorised public transport services of any sort. On top of that, commuting by public transport is very costly for the poor, whether in urban or rural locations. Having said that, Latin America can be described as a place where they have highly urbanised societies. Latin American countries are normally set up with big megacities such as São Paulo, and Rio de Janeiro in Brazil, Mexico City, and Buenos Aires, Argentina, the four of which feature in the 25 biggest cities in the world (Brinkoff, 2012). Latin American emissions from transportation are however growing, from which a majority are sourced form light duty vehicles (LDVs) in metropolitan areas. Forecasts currently suggest that new fuels and vehicles could reduce emissions per kilometre by 30 percent by 2030, but car use is expected to grow by 300 per cent during the same period (McAndrews et al., 2010).

Developing countries may urbanise more rapidly, within different political and institutional contexts, and with some different technologies. Many countries and cities are investigating various policies to reduce carbon emissions from transport in the hope of reaping both economic and social benefits at the same time. The increase in carbon emissions is only a part of the problem as countries are coping with many other transport externalities, such as air pollution, congestion, safety and social exclusion, amongst others. Various studies have tried to explain the relationship between economic growth and various environmental variables, during the course of the past decades, the debate regarding the worries and adverse effects of a worsening environmental state has increased. Air pollution, alongside water pollution, has been cited as the result of increased and uncontrolled human activities at different stages of economic development as such as agriculture, industries, energy generation and transportation. As described by the Environmental Kuznets Curve hypothesis, the take-off stage of development and industrialisation process can lead to environmental damage and to greater use of natural resources, more emission of pollutants, the operation of less efficient and relatively ‘dirty’ technologies and disregard for the environmental consequences of growth (Sanglimsuwan, 2011). At higher levels of development there is an increased environmental awareness and enforcement of environmental regulation that can lead to a gradual decline of environmental degradation. Pollution increases as a country develops, decreases once the threshold GDP is reached, and then begins decreasing as national incomes continue to increase.

Notwithstanding, some Latin American countries have already taken steps to curb the increase in carbon emissions. Brazil is the leader in the use of biofuels and Mexico is often remarked as a leader in climate change mitigation (McAndrews et. al., 2010). Some of the mitigating measures the countries have already taken also include demand management. There is a continent-wide move to collective transport (CEPAL, 2010), and steps in urban planning such as that witnessed in Curitiba, Brazil are testament to this.

IV. Emission Trends in Latin America and Factors That Influence Transport Sector Emissions

Factors That Influence Transport Sector Emissions

Population and Urbanisation

The region encompassed by Latin America and the Caribbean had a total population of 511 million in 1999 and is projected to reach 809 million by 2050 (UN, 1999). For the four Latin American countries covered by this paper, the total population is projected to increase by an average of 25 per cent from 2000 levels to 2050: 26.9 per cent in Argentina, 21.7 per cent in Brazil, 23.1 per cent in Chile and 30.5 per cent in Mexico, according to data by the United Nations Population Division.

As recorded in 2000, three quarters of the Latin American population lived in urban areas, where urbanisation has witnessed higher rates of growth amongst cities of medium size such as Córdoba (Argentina), Santiago de

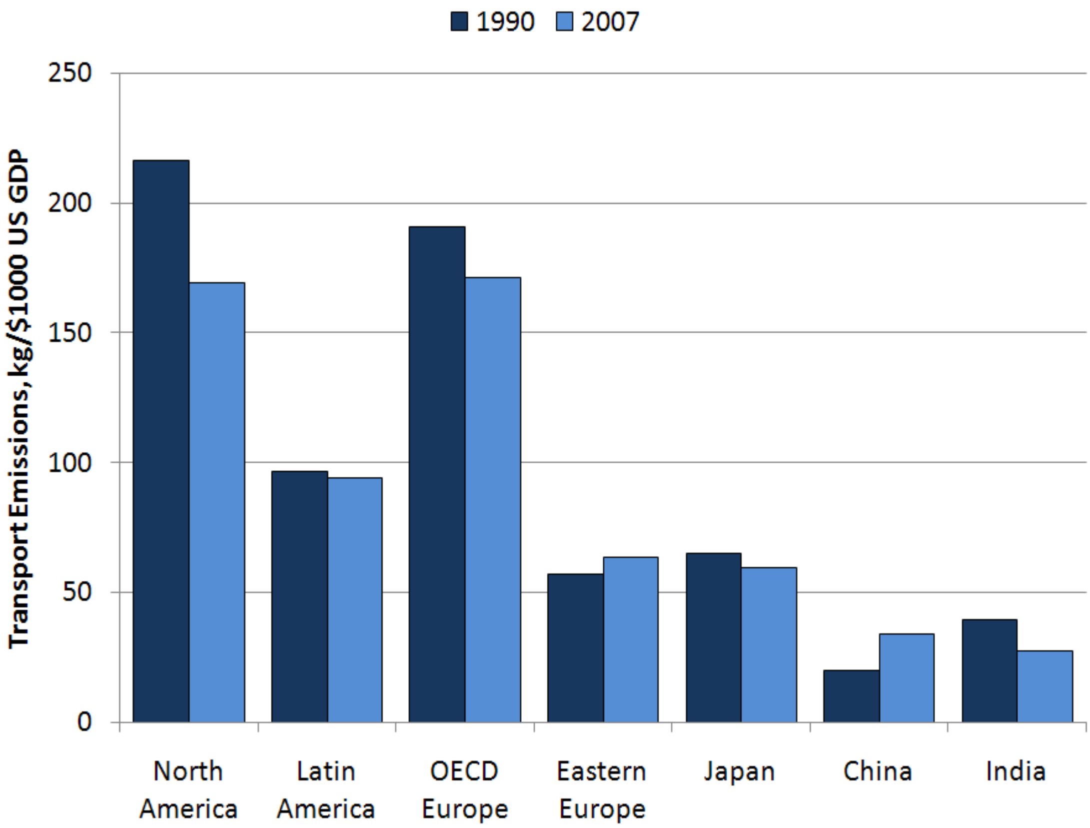
Chile, Guadalajara, (Mexico) and Belo Horizonte (Brazil) rather than the megacities such as Buenos Aires, Mexico City or São Paulo (Brea, 2003). Urbanisation rates for the four Latin American countries are expected to rise by an average of 22 per cent from 2000 levels to 2050: 22.5 per cent in Argentina, 18.6 per cent in Brazil, 18.6 per cent in Chile and 28.7 per cent in Mexico (figures from UN Statistics website).

Motorisation trends

The dominant vehicle type in Latin America is the light duty vehicle (LDV), most of which are passenger cars. 60 per cent of all road transport emissions in Latin America are attributable to urban areas, where LDVs are liable for over 50 per cent of urban emissions (Schipper et al., 2010). Car ownership in Latin American countries is relatively low, especially if compared to North American levels. However, the Latin American region, car ownership, use, and carbon emissions are noticeably greater than what could be assumed by looking at their GDP or population figures. As can be observed in the chart below, the ratio for Latin America is the highest amongst non-oil producing developing regions, and held nearly constant during the 17-year period depicted in Figure 1. For the world as a whole the transport emissions as a ratio to the GDP has declined by about 20 percent since 1990 (IEA, 2009). For Latin America, the ratio of road transport carbon emissions to GDP has declined slightly by less than 0.5 percent per year. In other words, transport emissions in Latin America have increased at almost the same rate that GDP has grown (Schipper et al., 2009a).

Motorised vehicle traffic is a prominent feature on the streets of Latin American cities. Transport emissions in Latin American are mainly produced from the road sector, up to 85 per cent, with air and rail accounting for the remaining 15 per cent (Schipper et al., 2010). From the 85 per cent of transport emissions coming from the road sector, about half come from

Figure 1. 1990 and 2007 Carbon Emissions for Road Transport per Unit GDP by Region



Note: 1990 data for India are for 1996; there is no 1990 data available for road transport only.

Source: Schipper et al. (2010)

passenger traffic and half from freight travel. 60 per cent of road transport emissions in the region were associated with urban areas, with light duty vehicles responsible for more than half of urban emissions (Emmerson et al., 2011). Schipper et al. (2009a) also relates that trends show increasing automobile ownership and use, and that, relative to GDP, growth in carbon emissions may increase faster in Latin America than in other developing countries.

However, two aspects of the Latin American scenario must be considered. There exists a wide disparity amongst the countries, from the higher earning countries such as Mexico, Argentina, Brazil and Chile to

Nicaragua, Bolivia, El Salvador and Paraguay on the other end of the spectrum. From the higher income countries Mexico possesses the highest vehicle ownership (number of cars per 1000 people), closely followed by Brazil, and the two of which are significantly ahead of the rest of Latin America (Schipper et al., 2010). A contributing factor affecting Mexico, and to an extent the Central American countries, is the large number of used cars from North America entering their countries.

Fuel Use

Motor gasoline and diesel dominate the fuel used in the transport sector in the Latin American countries (Timilsina and Shrestha, 2008). Fuel economy is projected to get more efficient, from 11.8 litres per 100 kilometres in 2000 to 9.4 litres per 100 kilometres in 2030 and to 8.3 litres by 2050, an improvement of around 20 per cent (Schipper et al., 2009a). Whereas the price of gasoline in a majority of Latin American countries is higher than in the US, diesel is significantly cheaper, often maintained artificially cheap by government intervention for socio-economic reasons, such as the case in Mexico (Timilsina and Shrestha, 2008).

A curious point regarding Latin American fuel use is the relatively high penetration, compared to other developing economies, of biofuels, particularly in Brazil, where it accounts for 25 per cent of all road fuel, and 90 per cent of all biofuel use in Latin America, whereas at the other end of the spectrum Mexico, the other dominant producer of carbon emissions in Latin America there is almost no biofuel use and the fuel currently used has a higher carbon dioxide content (Schipper et al., 2010).

However other models such as MODEC (Schipper et al., 2010) have predicted increase in fuel use per kilometre due to the increasing congestion, especially in urban areas, even cancelling a few benefits brought about by improved fuel economy in vehicles.

Modal Shares

Road transport has been the most important mode of transport in the Latin American countries, most notably in the smaller Central American countries such as Guatemala, Honduras, El Salvador and Panama, where road transportation is the only existing mode of transport. Timilsina and Shrestha (2008) report that apart from Colombia, Chile and Argentina, every other Latin American country has seen an increase in road transport activity; in Latin America road transport accounted for 90 per cent of transport sector fuel use and carbon emissions. This general shift towards the road transport sector was in combination a reduced reliance in domestic air transport and the use of inland waterways such as rivers. Rail transport has never been a significant mode of transport in Latin America, despite the present of some albeit small networks in Argentina, Peru and Mexico.

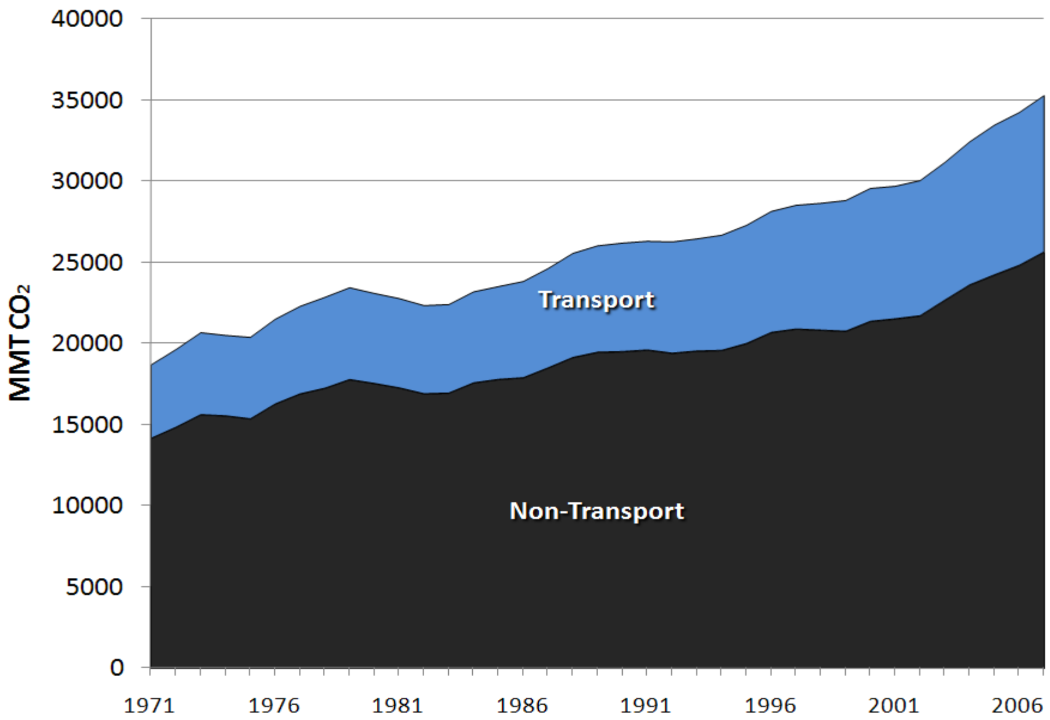
Data from the IEA indicate that direct emission increases from tailpipes have been driven in large part by the rising importance of fossil fuels for transport, especially in populous Brazil, where the use of ethanol did not keep pace with the demand for automobile fuels after 1990. Emissions from other sectors in Latin America grew less rapidly than those of gasoline. Thus the importance of road transport in Latin America emissions has increased over time (Schipper et al., 2009a).

Carbon Emissions Trends in Latin America

Since 1971 the share of the transport sector in the emission of carbon dioxide into the atmosphere has constantly risen (see Figure 2). It has attained, as of 2007, a 23 per cent contribution to total global emissions (IEA, 2009; Schipper et al., 2010).

The percentage of carbon emissions due to transport is 34.5 percent in Latin America in 2007 (IEA, 2009) Latin American countries also had a higher percentage of transport carbon emissions on the same year on average than all other sectors (IEA, 2009).

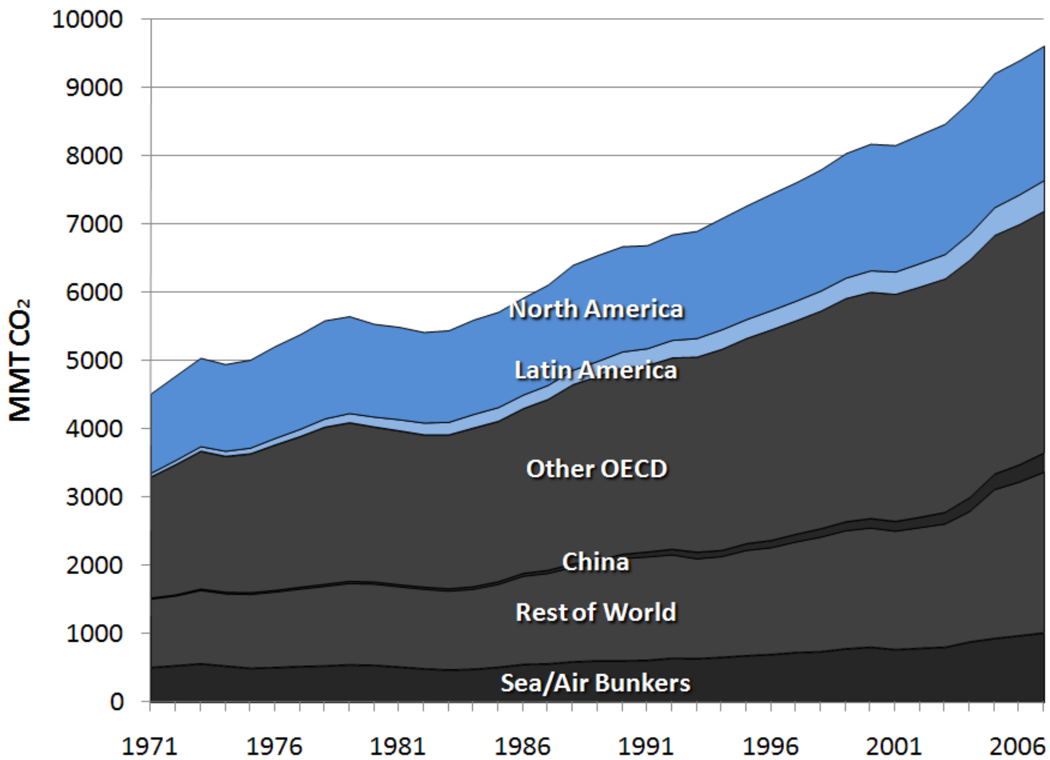
Figure 2. Global Carbon Dioxide Emissions: Transport vs. Non-transport



Source: Schipper et al. (2010)

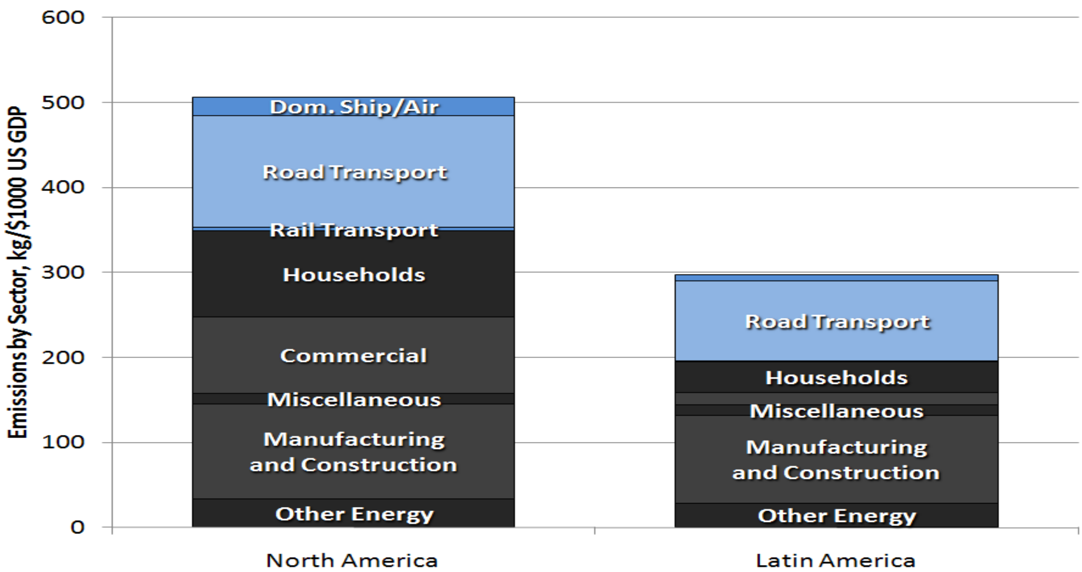
In global terms, Latin America can be observed to contribute to a small share of total carbon dioxide emissions. North America had in the past and is to the present still responsible to a substantial share of emissions. Emissions produced in Latin America for all transport modes are one of the highest amongst the developing world, however they are still substantially lower than North America, Europe and other developed regions (see Figure 3). For Latin America, the component for road transport represents a third of total carbon dioxide emissions, which is greater than the world average share, and surprisingly higher than what it is for North America (see Figure 4). Schipper et al. points out that 'this is due not only to the relatively high motorisation in Latin America, but also to the low usage of coal in other sectors and high usage of hydroelectric power' (2010: 17), and biomass or ethanol in countries

Figure 3. Global Carbon Dioxide Emissions: By Region



Source: Schipper et al. (2010)

Figure 4. Carbon Dioxide Emissions: North America In Comparison to Latin America



Source: Schipper et al. (2010)

like Brazil.

In comparison with the whole world as a whole, carbon emissions in Latin America are more heavily concentrated in transport which produces 35 percent of its total emission, compared to a 24 percent transport share throughout the world. Furthermore, transport emissions are concentrated in road transport, which accounts of over 90 percent of the region's transport emissions (Schipper et al., 2009b). In consideration of the congestion in most large Latin American cities, it has been recommended to curb the growth of vehicle ownership and use to in turn curb the growth of carbon dioxide emissions (Schipper et al., 2009b).

V. Objectives and Scope

This study intends the following objectives:

1. To check whether carbon emissions from the road transport sector in 2050 can witness a reduction of 50 per cent or to the same level of emissions in 2000, achieved through road transport management.
2. To check whether the visioning-backcasting model can be used to achieve that desired target.

The scope of this study will cover the following parametres:

Latin American Countries

Of the Latin American countries, four have been chosen: Brazil, Mexico, Argentina and Chile. The four countries selected in the study are the biggest, based on 2011 GDP per purchasing power parity (PPP) levels, economies in Latin America – Brazil (1st), Mexico (2nd), Argentina (3rd) and Chile (6th) (figures from World Economic Outlook Database). These four aforementioned countries also post the highest carbon emissions per capita within the region, in 2008 levels: Chile (4.4 tons per capita, 2nd highest), Argentina (4.4 tons, 2nd highest; same with Chile), Mexico (3.8 tons, 4th highest) and Brazil (1.9 tons, 7th highest) (figures from IEA, 2011).

Transport sector

This study will attempt to assess a potential of carbon emissions reduction in road transport, a sector in which CO2 emissions reduction are generally believed difficult (Matsuoka, 2011). Hence this paper will only consider road transport, both intercity and intracity for passenger transport. Emissions for rail transport would have been included but for the countries chosen, and as of Latin America as whole, railroad infrastructure is fairly minimal and is far overshadowed by other transport sectors such as aviation and shipping. The emissions coming from the aviation and maritime sectors were determined to put into perspective against the overall emissions produced by the transportation sector, but the sectors were not taken into consideration as perhaps including them would comprise of enough material that would warrant further study and investigation.

Emissions

Only carbon dioxide emissions have been considered. Other air pollutant emissions such as particulate matter and nitrogen oxide have been left out.

VI. Methodology

The estimation that this study will make shall proceed through the following steps:

1. Establishing the initial settings: In this step, the basic quantitative parametres for calculation and analysis, such as the different metrics

(GDP, population, etc.) the target year, the targets to be implemented and the different preconditions shall be determined.

2. Establishing a vision of the future society: This step would entail creating a representation of the transport needs required by the society in question in the target year by imagining the structure of that society. This perceived vision can be based on certain projections or aspirations. Perhaps what is essential in this step is to be able to map out a future society that can serve as a prerequisite for posterior analysis, with the intention of being able to determine the transport conditions that meet the necessities of the society that has been visualised.

3. Establishing a vision of a desired structure of future transport: This step intends to ascertain the kind of transport policy packages that will be implemented on the basis of the society of the future visualised on the previous step.

4. Conducting quantitative analysis and analysing the results.

Backcasting

Various studies which have involved transport sector emissions have employed the traditional forecasting approach. Forecasting is done through the extrapolation of existing trends and politics to predict the possible future outcomes. It is deemed useful in predicting the baseline scenario but is considered to be limited in terms of providing creative and trend breaking solutions for complex and long term problems, such as those in the transport sector (Hickman and Bannister, 2007).

This paper has employed the backcasting approach, often referred to as the opposite of forecasting. It involves visioning the desirable outcomes in the future and identifying measures that need to be taken to reach the desirable outcomes. It also provides the times, when policies need to be implement to achieve the desired outcome.

The following table highlights the main differences between forecasting and backcasting.

Table 1. Forecasting vs. Backcasting

MEASURE	**FORECASTING**	**BACKCASTING**
Philosophy	Justification as the context Causality determinism	Discovery as the context Causality and intentions
Perspective	Dominant trends Likely futures Possible marginal adjustments Focus on adapting to trends	Societal problems in need of a solution Desirable futures Scope of human choice Strategic decisions Retain freedom of action
Approach	Extrapolate trends into future Sensitivity analysis	Define interesting futures Analyse consequences and conditions for these futures to materialise
Methods and techniques	Various econometric models Mathematical algorithms	Partial and conditional extrapolations Normative models, system dynamic models, Delphi methods, expert judgment

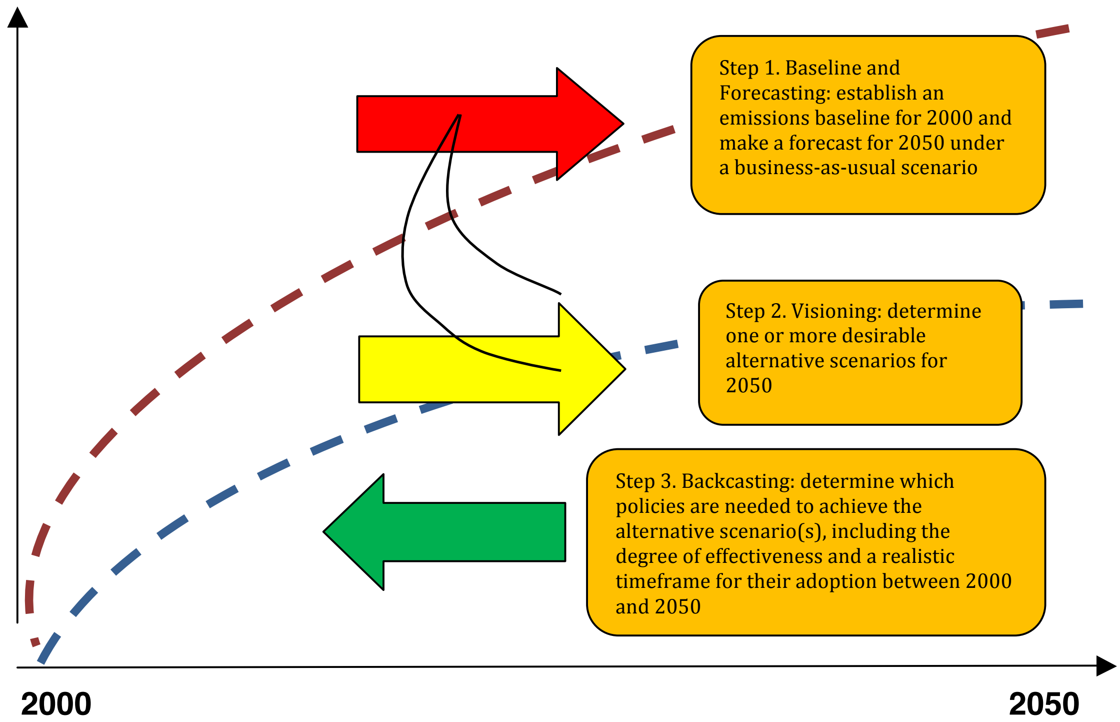
Source: Emmerson et al. (2011)

Through its initial use to analyse future energy options (Robinson, 1982), backcasting is concerned not with what futures are likely to happen, but with how desirable futures can be attained. It involves working from a particular desirable endpoint to the present in order to determine the physical suitability of that future and what policy measures would be required to reach that point (Robinson, 1990). From the present scenario, the analysis would show what needs to be changed to get to the backcasted future. The outcome is, hence, assumed as opposed to derived, and traced backwards to the initial year or 'base year'.

The use of backcasting has had a strong tradition in Scandinavian studies over the past twenty years (see Höjer and Mattsson, 2007). It has also been chosen to be a method in a few European projects (see Hickman and Bannister, 2007). Other studies involving carbon emissions has involved the use of the method for India (Saxena et al., 2009), the entire American continent (Schipper et. al., 2010) and Southeast Asia (CAI-ASIA, 2010) could be observed.

The visioning-backcasting approach is illustrated in the following diagram:

Figure 5. The Visioning-Backcasting Approach



Source: CAI-ASIA (2010)

ASIF Formula

Atmospheric emissions can be quantified by adopting either a top-down or a bottom-up approach. The top-down approach starts with data describing total polluting activity throughout the whole geographical area of interest, such as total national petrol sales for calculation of road transport emissions. This is related to the magnitude of the associated air pollution source by means of an emissions factor that can be obtained by laboratory measurement of a representative sample of engines of vehicles under simulated typical operating conditions. After which spatial disaggregation of a top down emissions inventory is done by assuming local emissions are proportional to some other variable that can reasonably be assumed to have a similar geographical distribution to that of the polluting activity, such as population density (Colville et. al., 2000).

In contrast, the bottom up approach starts with geographically resolved data, for example traffic flow. For some sources, emissions data are determined directly by measurement of each individual source. Especially for transport emissions where a large number of small individual sources are involved, emission factors need again to be used. Total emissions for a geographical area of interest can then be obtained by summing all individual contributions (Colville et. al., 2000).

The ASIF (an acronym for Activity Structure Intensity Fuel) methodology is a bottom-up methodology which can be used for calculating transport emissions based on four main determinants. This stipulates that emissions generated by the transport sector are dependent on the four following factors:

1. The level of travel activity (A) in passenger kilometres (or tonne per kilometre for freight)
2. The mode structure (S)
3. The fuel intensity of each mode (I) in litres per passenger kilometre, and
4. The carbon content of the fuel or emission factor (F), in grams of carbon or pollutant per litre of fuel consumed

The relationships discussed in the analysis of travel activities can be mathematically formalised in the following formula:

$$\mathbf{G = A^* S_i * I_i * F_{i,\,j}}$$

wherein:

G = carbon emissions from the transport sector,

A = total travel activity (expressed in passenger- or tonne - kilometres)

S = a vector of the modal shares

I = the modal energy intensity of each mode *i*,

$\mathbf{F_{i,\,j}}$ = the sum of each of the fuels *j* in mode *i*, using standard IPCC coefficients to convert fuel (or electricity) used into carbon emissions.

i = mode variable

j = fuel variable

Each of the components of the formula could respond at different rates to different underlying factors such as incomes, prices, policies, technologies, and other factors. The same formula can also be used to calculate other pollutant emissions, and results can be converted into mass per passenger kilometre or tonne kilometre (Emmerson et al., 2011).

This analytical methodology would not only analyse the trends but will also be able to aid in providing the framework for policy analysis, as Schipper et al. (2000) argues that it allows the observation of the effects of the recommended policies in a structured manner.

VII. Building The Model

Backcasting methods deal with ‘drivers’, or otherwise known as the primary elements that induce transport movement, such as economic metrics such as GDP, population levels and fuel prices. Additionally, along with population, GDP is a useful normalising tool to adjust for economic disparities between regions (Schipper et al., 2010).

Construction of the Baseline Scenario

The first step in the backcasting process is the establishment of the business as usual (BAU) scenario based on the current trends exhibited by the Latin American countries. Therefore, the BAU scenario would be an image of what would take place in the future given there would be no transportation interventions introduced and if the trends shown in the past will carry on. The BAU scenario was determined from 2000 to 2050, with 2000 being the 'base year' for the calculations to be carried out.

Forecasting the Number of Vehicles

Vehicle forecasting has been performed through the use of econometric regression with GDP per capita obtained from the United Nations Statistics Database. The trends in the figures for vehicles registrations in a country with GDP per capita are then used to calculate the elasticity of growth. Vehicle numbers (*parque automotriz or parque automotor* in Spanish and *frota de veículos* in Portuguese) figures were taken from ADEFA for Argentina, DENITRAN for Brazil, INE for Chile and INEGI for Mexico.

Local Transport Activity

The average vehicle per kilometre travelled (VKT) by each vehicle type was derived from previous studies (Schipper et al., 2009a, Schipper et al., 2010, Timilsina and Shrestha, 2008). VKT figures are assumed to go up annually by 1.2 per cent to reflect the capability of the society to absorb and consequently adjust to the ever increasing price of fuel, and the capability of the national governments of the selected countries to construct the infrastructure in response to the sustained increases in transport activity (CAI-

ASIA, 2010). That being said, capping limits have also been put into place as stipulated in previous literature (see Dargay et. al., 2007) to be able to simulate more realistically the capability of the transport structures in place to adjust to travel activity.

Fuel Efficiency

For the simulated baseline scenario, it is considered that only the fuel economy of light-duty vehicles (LDVs) is assumed to increase, as has been observed by the International Transport Forum (CAI-ASIA, 2010). Fuel economy will be considered to be of the same current values for the rest of the modes of transport.

Emission Factors

The carbon dioxide emission factors, expressed in grams per kilometre, are derived by multiplying the carbon content of the fuels by the fuel efficiencies of the groups of vehicles (Schipper et al., 2010). The emission factors applied have been acquired from various previous literature (Schipper et al., 2009a, Schipper et al., 2010, Timilsina and Shrestha, 2008).

Urbanisation ratios

The urbanisation ratio for the countries used for this study have been retrieved from the United Nations Population Database. The ratio is implemented to be able to distinguish fleet movements from two classifications: urban and rural. It has been decided that freight movement would be excluded as an urban fleet movement. CAI-ASIA (2010) argues that vehicles that travel within cities would be fitted with more advanced technologies, such as better fuel efficiency rates, and travels lesser than rural vehicles. However, no segregation has been made on that basis as no historical data and research has been found.

Vehicle occupancy

Vehicle occupancy is a ratio for the amount of people estimated to be in a vehicle. CAI-ASIA (2010) argues that would be different between low GDP PPP and high GDP PPP scenarios. For a low GDP PPP scenario, the society would stick to the present fleet but increase occupancy levels in vehicles, whereas for a high GDP PPP scenario occupancy rates are assumed to decrease as people, with their higher incomes, are assumed to prefer personal vehicles. For this study, a weighted ratio was used in lieu of separate calculations for a high GDP PPP scenario and a low GDP PPP scenario. The ratios have been sourced from different previous literature (Schipper et al., 2009a, Schipper et al., 2010, Timilsina and Shrestha, 2008).

Setting the Targets

This study intends to be able to determine as to whether the transport emissions for the Latin American countries selected for the study will be able to apply and achieve a 50 per cent reduction in carbon emissions in their respective transport sectors by 2050 or to the levels recorded in 2000. A 50 per cent reduction could be considered as a rather ambitious target, especially for developing countries which seek economic betterment. However, this target is not as ambitious as it follows the evolution of literature regarding emissions reduction (see CAI-ASIA (2010), Schipper et. al. (2010)). The United Nations Climate Change Conference held in Cancún, Mexico in November 2010 culminated in the drafting of the Cancún Agreement, which was a follow through of the Copenhagen Accord the year prior. The Cancún Agreement stipulated that severe cuts in the emission of GHGs must be carried out and to be able to hold on to the long-term target of keeping the rise in global average temperature below 2 degrees centigrade above pre-industrial levels (UNFCCC, 2011). In addition, the IPCC (Intergovernmental Panel on Climate Change) had carried out a calculation that estimated a reduction in emissions of between 50 per cent to 85 per cent of current levels would be needed to achieve that target posted by Cancún, an observation also echoed by Oka (2011). Matsuoka insists that the target looks very challenging on paper and that it has not been set 'as a political numerical value, but one that is based on the scientific knowledge of the IPCC' (2011: 3).

Another issue arises with regards to the setting of targets that deals with the transport sector. As has already been highlighted, transportation is a derivative demand, and as such is highly susceptible to the ramifications caused by other industries and the environment that surrounds transportation. It can then be assumed that the industrial composition of the setting in question, whether at city, country or regional level, has to be altered to attain massive reductions from carbon emissions resulting from the transport sector.

Images of the Future

Creating the Desired Images

For this paper, two images of the future have been made up for the countries involved in the study. These visions of the future should lead to two diverging paths. Schipper et al. (2010) has defined two visions: one of *globalisation*, which takes into consideration that the future will feature extensive international trade between countries whose population and economic activity tend to be based around a handful of cities, and that of *glocalisation*, which relates a scenario wherein socio-economic activity is performed with lesser travel and movement due to infrastructures in place. CAI-ASIA on the other hand has used two different scenarios: *demand management driven development*, wherein countries are to put into place policy packages that give priority to 'compact and transit-oriented urban development, aggressive integration of public transport, non-motorised transport and other policies aimed at managing transportation demand (2010: 22), and *technology-driven development*, wherein the preference is placed on ‘high levels of personal motorised mobility in cities exist as transport infrastructure are developed in response to growing motorization and traffic but where emission growth has been offset’ (2010: 22) because of technological improvements such as that in fuels and engine efficiency. The images created by CAI-ASIA (2010) have been preferred over the ones created by Schipper et. al. (2010) due to the fact that Schipper et al.’s (2010) images were made for both North and South America, whereas CAI-ASIA’s (2010) images of the future were specific to Southeast Asia, whose countries socio-economic conditions are much more similar to the four focal Latin American countries for this study.

Image 1. Demand-Management Driven Development

In this image, high economic development would be projected to continue for the subject Latin American countries. Population growth rates and trends in urbanization would also be expected to continue. Policies would be implemented to address and achieve a development more compact and more urban. The cities would observe high densities because policies for mixed use development and infrastructure for the integration of transport systems would be administered.

Due to high levels of economic growth, vehicle ownership rates would be increasing. However, travel activities are restrained by policy packages that deter vehicle activity, like road pricing and high parking charges. Occupancy in vehicles would be higher. Fuel costs would increase and subsidies removed or minimised, hence the society would embrace fuel saving through avoiding unnecessary trips or working from home as opposed to going to the office.

The increased levels in economic growth and urban density would permit the deviation of national government funds to provide methods of more efficient public transport options and non motorised transport options. Their increased accessibility to the society would encourage a shift to use public transport combined with walking or cycling. Non motorised transport options would be well integrated in the transport system. All in all, regardless of a higher level of vehicle ownership, travel activity would be made more efficient.

In terms of fuel efficiency, vehicles using fossil fuels would observe an improvement. Vehicles powered by alternative means such as electric and hybrid vehicles would be more accessible. Alternative fuels such as biofuels would be 50 per cent of the blend for petrol and diesel.

Image 2. Technology Driven Development

For this image of the future, economic growth would also be observed to follow the same trend as population levels and urbanization levels. The development of urban spaces would also carry on growing. A higher demand for personal motorised vehicles would arise however due to people having to travel daily from their houses on the cities' peripheries into the city centre.

The ownership of vehicles would also grow in line with economic growth. The restriction imposed on travel activities would be more lenient with fewer demand management regulations. Transport infrastructure in place would provide for motorised private transport as motorways would be in place to accommodate the growth in vehicles. The cities would tend to be less dense, therefore there would be a lesser incentive for governments to divert funds to allot for the construction of integrated public transport modes. Traffic systems would see an improvement.

The technological advancement for vehicle technologies would allow for the society to adopt alternative fuel vehicles, electric vehicles and hybrid vehicles which would compose the majority of the vehicles in the market. Fuel efficiency levels would see higher levels of improvement. Fuels available for vehicles would consist of higher blends of biofuels.

The images could be summarised in the table below.

Table 2. Comparison of the Two Images of the Future

FACTORS	**Image 1: Demand-Management Driven Development**	**Image 2: Technology-Driven Development**
Population and urbanisation	Current trends continue	Current trends continue
GDP per capita	Current trends continue	Current trends continue
Urban form	Large and highly dense cities	Large but less dense cities with smaller cities near large urban agglomerations
Fuel price	Higher	Relatively higher than BAU
Vehicle ownership	Current trends continue	Current trends continue
Vehicle travel	Increases but more moderately	Increases aggressively
Vehicle occupancy	Increases due to the high costs of driving as well as the provision of quality public transport modes	Decreases due to the needs for individual transport
Vehicle technology	Still dominated by gasoline and diesel vehicles but with substantial share of alternative fuel vehicles such as LPG, CNG, etc.	Electric, electric hybrids and alternative fuel-powered vehicles dominate the market
Vehicle efficiency	Nominal improvement from current levels	Significant improvement from current levels
Public transport	High quality, sufficient, integrated	Not fully developed due to insufficient demand
NMT facilities	High space allocation for NMT modes	Minimal space for NMT modes as private motorised modes dominate
Freight	Half is shifted to railways; highly effective freight logistic systems	More than half is shifted to railway; highly effective freight logistic systems
Traffic management	Highly improved	Highly improved but sheer vehicle activity negates some of the

		effects
People's values	Gives priority to public and non-motorised transport	Gives priority to individual transport

Source: CAI-ASIA (2010)

VIII. Policy Packages

Identifying Policies To Be Used

Another set of general assumptions that will affect this study is the policy packages to be employed that would be expected to induce a reduction to carbon emissions. For this paper, the policies will cover transport policies. Therefore the policies will not include discourses related to, for example, the dissemination of power sources which produce lesser emissions for electric-powered vehicles. The idea is that the implementation of the policy packages which are subject to evaluation would give better prominence to the targeting of problems inherent in the transportation sector, such as in the transport modes and engine technologies (Matsuoka, 2011).

Emissions from transport could be reduced through the use of the following strategies: avoiding unnecessary travel through the reduction of overall passenger vehicle-kilometre travelled, shifting from the use of private motorised modes of transport to public transport and non-motorised modes of transport for passengers, and improving fuel efficiency to achieve reduced emission factors across the various transport modes available (Dalkman and Brannigan, 2007).

Transport Research Laboratory (TRL) (Emmerson et al., 2011) has proposed the integration of the 'Fuel' component (F) into the 'Improve' (I) component. Hence there would be just three policy groups.

These three policy groups are implemented in a different way in developed and developing countries, as explained in the table below. The

Table 3. Policy Strategies and Differences in Approach

Strategies	Developed countries	Developing countries
Avoid	Reduced vehicle-kilometre based on transport demand management and land use plan. Increase local production and shorten supply chain.	Avoid occurrence of unnecessary vehicle-kilometre by land use plans and transport plans
Shift	Shift the travelling means of people from private cars to non-motor transport and public transport, and from aeroplanes to railways and public transport. Shift freight transport mans from trucks to railways and ships.	Development of travelling of passengers or transport of goods that have the least carbon dioxide emissions. Secure alternative transport means that are more attractive than private cars and prevent shifting from non-motor transport and public transport to private cars
Improve	Improvement of conventional automobiles. Downsizing of automobile engines. Electrificaiton of railways (passenger and cargo).	Promote smaller and efficient automobiles by developing clean automobiles and fuels. Design innovation of conventional non-motor transport (such as bicycle taxis)

Source: Dalkmann in Leather et. al. (2010)

policies, and some examples already being implemented in the subject countries, are detailed as follows.

Avoid

Policies classified under this category is attributed to those that would avoid the production of emissions from motorised modes of transport, such as the introduction of non-motorised transport, fuel taxes and subsidy reform, parking fees, low speed zones, car sharing and/or carpooling incentives, bike rentals and green zones. To provide examples in the setting, in Argentina, the Buenos Aires Sustainable Transport Plan details measures to induce non-motorised transport (CEPAL, 2010).

Shift

Policies classified under this category would consist of those that encourage the shift of imperative travel activity from a highly polluting mode to one that is of a lower emissions intensity, such as that of bus rapid transit or metro rail transit systems, intercity tolls, high occupancy vehicle lanes, the improvement of feeder bus services and general intermodal connectivity. To provide examples in the setting, in Argentina, Brazil and Mexico rail infrastructure is being expanded to induce a modal shift from cars to rail (CEPAL, 2010).

Improve

Policies classified under this category includes strategies that would result in the improvement of energy efficiencies or carbon intensities of motorised vehicles attained through technological interventions, such as more stringent vehicle emissions standards, alternative vehicles and fuels, fuel economy improvement policies, intelligent transport systems, and improved traffic management. To provide examples in the setting Brazil is one of the leading proponents of biofuel use in the transport sector, whereas Chile intends to introduce Euro IV standards for new public transport buses (CEPAL, 2010).

Determining the Impact of Policies

To be able to understand how policies would effect the carbon emissions, individual policies from each policy group (Avoid, Shift and Improve) were selected and quantified. The table below enumerates the changes applied to the quantification of the backcasted estimations.

Table 4. Policy Packages and Quantified Impacts

Policy Referred in Calculation As	Strategy Type	Impact in Image 1	Impact in Image 2
Fuel Economy Improvement – Passenger Vehicles (Policy 1)	Improve	10 per cent improvement by at 2020, 15 per cent by 2030, 30 per cent by 2050	20 per cent improvement by 2020, 35 per cent by 2030 and 50 per cent by 2050
Alternative Vehicles (Policy 2a)	Improve	10 per cent conversion to vehicles powered by other means, 20 per cent	more than 50 per cent conversion to vehicles powered by other means
Alternative Fuels (Policy 2b)	Improve	10 per cent by 2012, 25 by 2030, 35 by 2040 and 45 by 2050	10 per cent by 2012, 40 by 2030, 60 by 2040 and 80 by 2050
Shift to Public Urban Transport (Policy 3)	Shift	40 per cent cumulative shift of motorised VKT from other urban passenger modes between 2020 and 2050	35 per cent cumulative shift of motorised VKT from other urban passenger modes between 2030 and 2050
Motorised Urban Passenger VKT Avoidance (Policy 4)	Avoid	45 per cent cumulative reduction in urban motorised PKT between 2020 and 2050	30 per cent cumulative reduction in urban motorised PKT between 2020 and 2050
Freight VKT Avoidance (Policy 5a)	Avoid	50 per cent cumulative shift of freight VKT to rail between 2020 and 2050	60 per cent shift of freight VKT to rail from 2030 to 2050
Shift Freight to Rail (Policy 5b)	Shift	50 per cent reduction in freight VKT between 2020 and 2050	60 per cent reduction in freight VKT between 2030 and 2050
Fuel Economy Improvement – Freight (Policy 5c)	Improve	10 per cent improvement by at 2020, 15 per cent by 2030, 30 per cent by 2050	20 per cent improvement by 2020, 35 per cent by 2030 and 50 per cent by 2050

Intelligent Transport Systems (Policy 6)	Improve	10 per cent increase in fuel efficiency from increase in speed by 2020, 15 per cent by 2035 and 20 by 2050	5 per cent increase in fuel efficiency due to increase in speed by 2020, 10 per cent by 2035 and 15 per cent by 2050

Source: modified table from CAI-ASIA (2010) and Schipper et al. (2010)

IX. Calculation and Results

The calculations of the results for the baseline scenario and the scenarios with the two images of the future applied have been carried out through a spreadsheet tool provided by CAI-ASIA. The baseline scenario is shown below and the results for the two images are shown in the graphs below and the interplay with the three different policy groups are shown below.

Backcasting results for Image 1

As shown through the backcasted model for carbon emissions, in Image 1 there will be an expected reduction in carbon emissions of 2159.26 million tonnes. In terms of policy interaction, ’Avoid’ policies contributed to 43 per cent of the cumulative reductions, whereas ’Shift’ policies contributed to 17 per cent and ’Improve’ policies contributed to 40 per cent. The target level of emissions at 540.64 million tonnes for the four countries is easily reached at 324.12 million tonnes.

’Avoid’ policies need to go hand in hand with ’Shift’ policies if the desired level of a 50 per cent reduction will be reached in the next forty years. The results suggest a ‘decoupling’ of Latin American society with their cars would produce a dramatic reduction to carbon emissions. Demand management, nevertheless, does not mean that there would be no need for introducing technological instruments. As the results show, ’Improve’ policies

Figure 6. Image 1 - Demand Management Driven Development

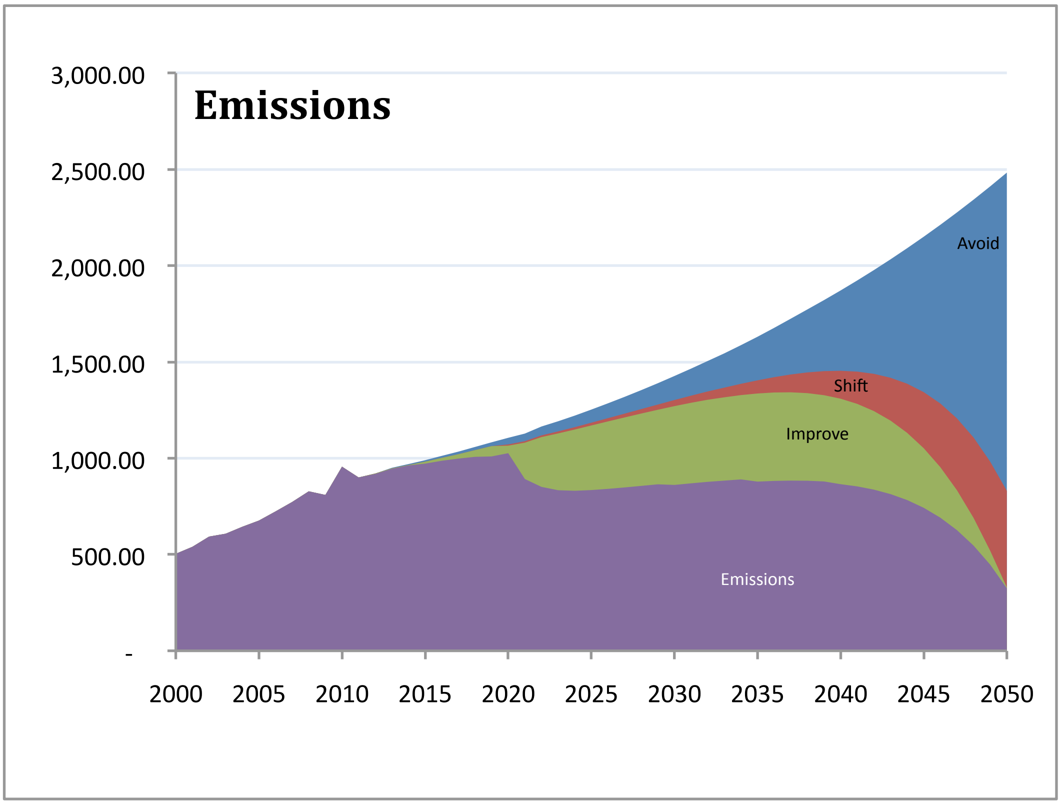
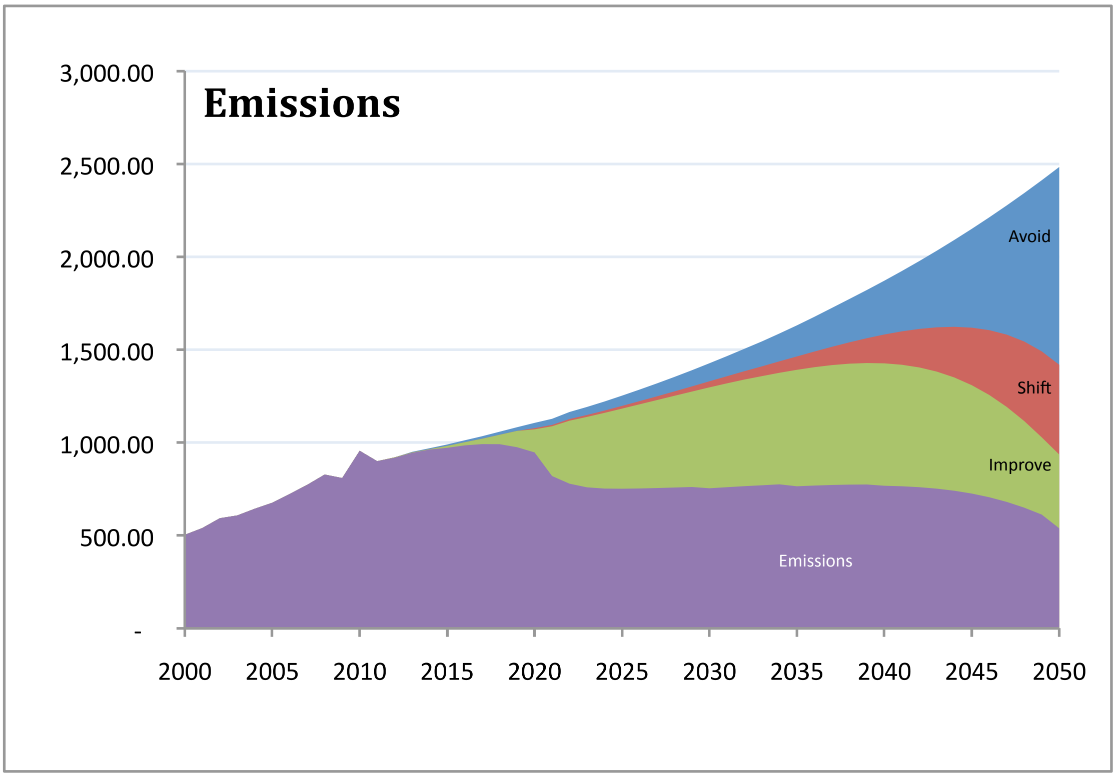


Figure 7. Image 2 - Technology Driven Development



are only just beaten by the ’Avoid’ policies by 3 per cent in terms of contribution to emissions reduction.

Backcasting results for Image 2

The scenario above will be able to reach an emission reduction of 1944.76 metric tonnes. In terms of the interaction of the policy packages, ’Improve’ comprised 56 per cent of the cumulative reductions in emissions, compared to 17 per sent for the ’Shift’ policies and 27 per cent to ’Avoid’ policies. However, in this scenario the target emission level is only just reached at 538.62 million tonnes, compared to the target emission level of 540.64 million tonnes, a 2 million tonne difference which is distinguishable nevertheless.

This image implies an aggressive implementation of high technology elements in the road transport scenario, which despite the high levels of economic growth compared to their other Latin American counterparts, the four Latin American countries might still find it hard to implement them as their income levels can still not be considered of ’developed’ level, and policymakers might deem it better to divert funds to other immediate social needs such as poverty alleviation.

X. Conclusions

The implementation of individual policy packages i.e. separate policy groups on their own are insufficient to achieve the emissions targets for 2050. According to the backcasted data, a combination of policy packages will be needed to achieve the emissions target of 50 per cent reduction. The scaling up of planning and investment to support this change is a major challenge to policymakers and planners at every level if changes in land use and transportation patterns are to contribute and bring the world to a low level of carbon emissions around 2050.

Climate change manifests a great threat to humanity and its environment, hence a rapid response to reduce and mitigate carbon emissions is imperative. Moving a shift to a low carbon economy maybe difficult to implement politically, and in times of economic hardship, it may prove even more tricky. For developing countries such as those in Latin America, who in line with their ambitions to achieve economic growth, however witness a faster growth rate in vehicle utilisation and vehicle stocks. Here one important predicament would be achieving a reform in current policies for the transport sector whilst it is still at the early stages of growth yet still be able to facilitate overall socio-economic welfare. Perhaps countries should revisit more previous sustainable examples which are already present within their backyard particularly in Curitiba, Brazil and the success of the bus rapid transit systems in some medium-sized Latin American cities such as Bogotá.

The best choice of policy packages will most definitely vary across countries and regions. Even though the countries included in the region could be said to be of a similar socio-economic setup, some of their individual characteristics might mean that some policies would be more appropriate for one but not for the other, for not only must the levels of economic development be considered in the creation and implementation of policy, but also the kind of economic activities, geographical considerations, the density of the population and to a certain extent, cultural values all in one way or another could contribute in influencing the conclusiveness and feasibility of policies and how they could induce changes in modal choices, infrastructural investments and transport demand management initiatives.

Of course the model presented can always be adjusted through arbitrary ways so that the target reduction could be achieved, but the assumptions stipulated below ensure that the ways in which the reduction can be achieved is actually achievable and can be practically applied in the four

Latin American countries' settings, again in consideration of particular country characteristics. Perhaps the next step for this study is to fine tune the elements of the model, in particular the formulation of the policies to be applied, the estimation of the reductions that the policy and/or combination of policies will produce and the induced effects that will be caused by more effective transport management and emissions mitigations techniques.

Finally, going back to the objectives set earlier in the paper, this study can be considered as another piece of literature that proves that the backcasting model is an effective tool in being able to look at future desirable scenarios and being able to determine the desirable pathways to achieve those desirable images of the future society.

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XII. APPENDICES : Backcasting Image 1

TOTAL (million tons CO2)

	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	503.766	676.2738	956.0677	989.7477	1106.113	1252.645	1427.059	1630.913	1871.369	2150.396	2483.376

TOTAL (million tons CO2)

	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Policy 1	503.8879	676.2738	956.0677	980.1126	1063.861	1183.244	1322.19	1481.95	1671.651	1893.037	2151.475
Policy 2a	503.8879	676.2738	956.0677	982.0424	1178.58	995.7721	1094.845	1230.966	1417.295	1674.433	2046.953
Policy 2b	503.8879	676.2738	956.0677	979.8662	1080.363	1206.353	1338.351	1506.315	1694.38	1929.786	2189.967
Policy 3	503.8879	676.2738	956.0677	982.0424	1079.901	1203.907	1348.026	1511.583	1703.617	1922.605	2169.314
Policy 4	503.8879	676.2738	956.0677	982.0424	1076.723	1195.8	1328.303	1465.002	1594.93	1672.028	1600.374
Policy 5a	503.8879	676.2738	956.0677	976.0204	1021.537	1127.424	1248.029	1385.089	1545.783	1729.376	1938.689
Policy 5b	503.8879	676.2738	956.0677	982.0424	1077.815	1197.744	1331.014	1466.841	1590.714	1643.247	1485.79
Policy 5c	503.8879	676.2738	956.0677	982.0424	1079.044	1200.914	1339.153	1487.529	1642.859	1773.906	1811.66
Policy 6	503.8879	676.2738	956.0677	982.0424	1043.904	1165.135	1307.81	1444.435	1637.841	1865.853	2094.612

TOTAL (million tons CO2) (Packages as Separate)

	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Avoid	809.133	1086.413	1555.351	1602.708	1762.53	1949.48	2147.44	2321.703	2404.336	2209.556	1320.816
Shift	809.133	1086.413	1555.351	1602.708	1770.719	1967.797	2188.607	2415.104	2617.808	2700.712	2457.154
Improve	809.133	1086.413	1555.351	1586.518	1597.623	1378.069	1474.105	1607.56	1814.985	2126.145	2521.351

TOTAL (million tons CO2)

	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Avoid + Shift	322.5593	676.2738	956.0677	982.0424	1065.246	1170.12	1270.584	1336.225	1309.15	1051.946	329.4119
Avoid +Improve	503.8879	676.2738	956.0677	971.936	1032.624	843.7157	879.429	915.8909	942.7553	900.8563	598.0069
Improve + Shift	503.8879	676.2738	956.0677	971.936	1036.221	850.2582	894.0502	948.7773	1020.093	1088.984	1060.449

TOTAL (million tons CO2)

	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050

ALL	0	676.2738	956.0677	971.936	1026.158	834.6812	861.4073	878.6003	865.161	742.5058	324.1166

TOTAL (million tons CO2)

	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Avoid	503.8879	676.2738	956.0677	982.0424	1071.78	1184.518	1302.215	1404.461	1454.047	1343.145	830.4462
Shift	322.4374	676.2738	956.0677	989.7477	1099.579	1238.247	1395.427	1562.677	1726.471	1859.197	1982.342
Improve	181.2067	676.2738	956.0677	979.6412	1067.024	917.2061	1017.883	1173.288	1427.38	1840.956	2478.081

TOTAL Emissions (million tons CO2) - Packages Interact

	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	503.766	676.2738	956.0677	989.7477	1106.113	1252.645	1427.059	1630.913	1871.369	2150.396	2483.376
Avoid	503.8879	676.2738	956.0677	982.0424	1071.78	1184.518	1302.215	1404.461	1454.047	1343.145	830.4462
Shift	322.4374	676.2738	956.0677	989.7477	1099.579	1238.247	1395.427	1562.677	1726.471	1859.197	1982.342
Improve	181.2067	676.2738	956.0677	979.6412	1067.024	917.2061	1017.883	1173.288	1427.38	1840.956	2478.081
ALL	0	676.2738	956.0677	971.936	1026.158	834.6812	861.4073	878.6003	865.161	742.5058	324.1166

Target Emissions	540.6412

	2050 Emissions
Avoid	1320.816
Shift	2457.154
Improve	2521.351
ALL	324.1166

Reductions

	%
Avoid	0.423416
Shift	0.173898
Improve	0.402687
	1

Backcasting Image 2

TOTAL (million tons CO2)

	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	503.766	676.2738	956.0677	989.7477	1106.113	1252.645	1427.059	1630.913	1871.369	2150.396	2483.376

TOTAL (million tons CO2)

	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Policy 1	503.8879	676.2738	956.0677	980.1126	1048.114	1159.589	1287.71	1438.1	1615.556	1821.886	2062.124
Policy 2a	503.8879	676.2738	956.0677	982.0424	1178.58	995.7721	1094.845	1230.966	1417.295	1674.433	2046.953
Policy 2b	503.8879	676.2738	956.0677	979.8662	1080.363	1206.353	1338.351	1506.315	1694.38	1929.786	2137.875
Policy 3	503.8879	676.2738	956.0677	982.0424	1079.99	1204.053	1348.265	1511.979	1704.251	1923.626	2170.977
Policy 4	503.8879	676.2738	956.0677	982.0424	1082.653	1208.811	1356.662	1526.49	1729.767	1968.366	2247.983
Policy 5a	503.8879	676.2738	956.0677	976.0204	970.5197	1052.555	1140.304	1247.748	1371.902	1510.994	1666.949
Policy 5b	503.8879	676.2738	956.0677	982.0424	1077.815	1197.604	1330.361	1464.555	1583.579	1622.296	1426.565
Policy 5c	503.8879	676.2738	956.0677	982.0424	1079.044	1200.446	1337.023	1480.228	1620.544	1709.75	1634.038
Policy 6	503.8879	676.2738	956.0677	982.0424	1043.904	1165.135	1307.81	1444.435	1637.841	1865.853	2094.612

TOTAL (million tons CO2) (Packages as Separate)

	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Avoid	503.8879	676.2738	956.0677	982.0424	1077.711	1197.389	1329.922	1463.664	1581.749	1618.531	1418.83
Shift	503.8879	676.2738	956.0677	982.0424	1076.276	1194.319	1323.607	1451.412	1557.506	1571.975	1337.447
Improve	503.8879	676.2738	956.0677	971.936	958.6202	767.8522	786.8061	834.4087	917.4222	1053.703	1219.294

TOTAL (million tons CO2)

	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Avoid + Shift	322.5593	676.2738	956.0677	982.0424	1071.266	1182.856	1297.255	1391.639	1426.521	1308.848	935.7349
Avoid +Improve	503.8879	676.2738	956.0677	971.936	952.7739	759.6462	769.6931	796.87	833.5154	856.0554	734.0442
Improve + Shift	503.8879	676.2738	956.0677	971.936	952.8698	759.8085	770.8117	800.3759	842.855	882.2492	823.3975

TOTAL (million tons CO2)

	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
ALL	0	676.2738	956.0677	971.936	947.064	751.7136	754.1527	764.8156	767.6846	725.6644	538.6185

TOTAL (million tons CO2)

	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Avoid	503.8879	676.2738	956.0677	982.0424	1077.711	1197.389	1329.922	1463.664	1581.749	1618.531	1418.83
Shift	322.4374	676.2738	956.0677	989.7477	1099.668	1238.112	1394.392	1558.888	1716.14	1840.713	2000.281
Improve	181.2067	676.2738	956.0677	979.6412	981.9106	821.5028	883.9564	1004.089	1212.533	1567.212	2086.259

TOTAL Emissions (million tons CO2) - Packages Interact

	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	503.766	676.2738	956.0677	989.7477	1106.113	1252.645	1427.059	1630.913	1871.369	2150.396	2483.376
Avoid	503.8879	676.2738	956.0677	982.0424	1077.711	1197.389	1329.922	1463.664	1581.749	1618.531	1418.83
Shift	322.4374	676.2738	956.0677	989.7477	1099.668	1238.112	1394.392	1558.888	1716.14	1840.713	2000.281
Improve	181.2067	676.2738	956.0677	979.6412	981.9106	821.5028	883.9564	1004.089	1212.533	1567.212	2086.259
ALL	0	676.2738	956.0677	971.936	947.064	751.7136	754.1527	764.8156	767.6846	725.6644	538.6185

Target Emissions	540.6412

	2050 Emissions
Avoid	1418.83
Shift	1337.447
Improve	1219.294
ALL	538.6185

Reductions

	%
Avoid	0.27141
Shift	0.168844
Improve	0.559745
	1